CHAPTER

2 Electrostatic Potential and Capacitance

Electric Potential Energy

(a) The electric potential energy for a point charge q_0 in the electric field of a stationary point charge q, with a distance r separating the charges is

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_0 q}{r}$$

If electric potential energy at infinity is considered to be zero.

(b) Work done by electric force on a charge when it is moved from A to B

$$W_{A\to B} = U_A - U_B$$

Electric Potential

(a) Potential is equal to potential energy per unit charge

$$V = \frac{U}{q_0}$$

The potential for a point charge q at any point at a distance r is

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

If potential at infinity is considered to be zero.

(b) Potential due to a collection of charges is the sum of the potentials due to each charge.

$$V_n = \frac{1}{4\pi\varepsilon_0}\sum_{i}^{n}\frac{q_i}{r}$$

(c) Potential due to a conducting sphere of radius r with charge q (solid or hollow) at a distance r from the centre

$$V = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{q}{r} \qquad \text{if } (r > R)$$

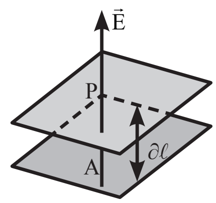
$$V = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{q}{R} \qquad \text{if } (r = R)$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R} \qquad \text{if } (r < R)$$

(d) Relation between electric field and potential

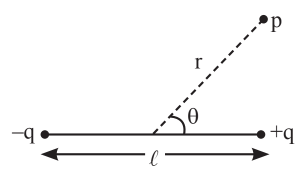
$$\left|\vec{E}\right| = \left|-\frac{\partial V}{\partial \ell}\right|$$

$$= +\frac{\left|\partial V\right|}{\partial \ell}$$



Electric Dipole Potential

(a) $V = \dfrac{1}{4\pi\varepsilon_0}\left(\dfrac{p\cos\theta}{r^2}\right)$



(b) Potential energy of a dipole in an external electric field

$$U(\theta) = -\vec{p}\cdot\vec{E}$$

Capacitors

Capacitance of a parallel plate capacitor

$$C = \varepsilon_0\frac{A}{d}$$

Also, $C = \dfrac{Q}{V}$

Electric Field Energy

(a) $U = \dfrac{1}{2}QV = \dfrac{Q^2}{2C} = \dfrac{1}{2}CV^2$

(b) Energy density of energy stored in electric field $U = \dfrac{1}{2}\varepsilon_0 E^2$

Combination of Capacitor

(a) When capacitors are combined in series,

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ...$$

(b) When capacitors are connected in parallel,

$$C_{eq} = C_1 + C_2 + C_3 + ...$$

(c) Spherical capacitor,

$$C = 4\pi\varepsilon_0\frac{ab}{b-a}, \qquad \text{(When outer shell is earthed)}$$

$$C = 4\pi\varepsilon_0\frac{b^2}{b-a}, \qquad \text{(When inner shell is earthed)}$$

$C = 4\pi\varepsilon_0 R$ (For a sphere of radius R)

(d) Cylindrical capacitor, $C = \dfrac{2\pi\varepsilon_0 l}{\ln\left(\dfrac{b}{a}\right)}$

Dielectrics

(a) Induced charge, $q' = q\left(1 - \dfrac{1}{K}\right)$

(b) Polarisation $P = \dfrac{\text{Dipole moment}}{\text{Volume}}$

$\vec{P} = \chi_0 \vec{E}$

$\dfrac{\chi_0}{\varepsilon_0} = K - 1$